Journal of Mechanical Engineering Research and Developments
ISSN: 1024-1752
CODEN: JERDFO
Vol. 45, No. 1, pp. 76-83
Published Year 2022

The Effect of Biodisel Mixture of Candlenut Oil *(Aleurites Moluccana)* on Fire Characteristics on Oil Burner

Digdo Listyadi Setyawan*, Nasrul Ilminnafik, Hary Sutjahjono, Friska Putri

Mechanical Department, University of Jember, Jl. Kalimantan Tegalboto No.37, Krajan Timur, Sumbersari, Kec. Sumbersari, Kabupaten Jember, Jawa Timur 68121, Indonesia.

*Corresponding Author Email: digdo@unej.ac.id

ABSTRACT

Burner design is crucial in determining the level and amount of emission during the combustion process. Poor atomization results in large ash particles and a higher particulate loading because the fuel droplets may be large enough to make it difficult to burn completely. The combustion of diesel oil is similar to the combustion of other liquid, solid or gaseous fuels and the chemical reactions involved are the same. The characteristics of the flame that can be used as a benchmark for burning a mixture of biodiesel and pertamina dex/ biosolar include: Flame temperature, flame height/length and flame color. The variables used in this study were B0 (Pertadex 100%), B10 (10% Biodiesel and 90% Pertadex), B20 (20% Biodiesel and 80% Pertadex), 30 (30% Biodiesel and 70% Pertadex). This research resulted that the addition of biodiesel mixture variations will affect the blue color composition, flame length and combustion flame temperature. The more biodiesel is added, the lower the percentage of blue value produced. The average value of the highest flame temperature at B0 at 40 l/m air variation is 984.8ºC. The lowest flame temperature value is at B100 at air variation of 30 l/m, which is 297ºC. The length of the flame is also influenced by the magnitude of the equivalence ratio, the longer the flame produced, B0 at = 0.3 is 791.198 mm long, while B0 at = 0.9 is 941.907 mm long.

KEYWORDS

Candlenut biodiesel, pertadex, oil burner, flame

INTRODUCTION

The current energy crisis has increasingly encouraged the development of clean and high-efficiency burners with gas emissions. Various types of burners and combustion systems have been studied and developed for industrial and domestic applications [1]. Unlike most other process equipment, burners use many parameters to operate properly and efficiently. Some of the parameters that affect burner operation and combustion emissions include: fuel composition, chemical process, operating conditions e.g. temperature, pressure, excess air, fuel rate [2]. Prior knowledge of these parameters is required to be able to design an oil burner that will optimize combustion and thermal energy generation. As part of this parameter, it is necessary to know the type of flame in the burner design. Mathew observed that combustion at low temperature and pressure emits nitrogen dioxide which is a reddish-brown gas and this contributes greatly to the formation of Ozone at ground level and acid rain [3]. Investigations carried out on fuel combustion show that there are two important groups of influential parameters: the type of fuel and the characteristics of the burner. The most important conclusion from this investigation is that each type of fuel requires a certain type of burner for combustion and operating parameters for optimal work [4].

Oil burners are used to burn liquid fuels ranging from light kerosene to heavy fuel oils. Most conventional liquid fuel burners are spray type in design which poses a number of challenges as observed by S. Jugjai and C. Pongsai [5]. These challenges include low combustion density, incomplete combustion with high CO and NOx emissions, relatively low and non-uniform heat flux among others. The purpose of the oil burner is to promote the efficient combustion of fuel oil. This can only be achieved through very precise fuel atomization, proper fuel/air mixing, high combustion temperatures, and sufficient residence time in the combustion chamber. Evaporation of the fuel to very ne particles occurs in a very short time when exposed to high temperatures. Atomization also increases the droplet surface area thereby promoting proper fuel/air mixing and complete combustion [6]. Air atomizing nozzles are categorized into internal and external mixed nozzle arrangements depending on where the fuel atomization occurs. In the internal mixture nozzle arrangement, the fuel is atomized by the compressed air in the nozzle. In this case the nozzle has a mixing chamber where atomization occurs. This type of adjustment is the most common due to its flexibility and the wide variety of flow rates, spray patterns and droplet sizes that can be achieved by adjusting the fuel and air pressures. In the external mixture nozzle arrangement, the fuel is atomized outside the nozzle orifice and the two liquids exit the separate orifices. This allows the pressure value to be adjusted independently and the fuel flow rate to be easily controlled. It is also possible to obtain a finer atomization of the liquid compared to the internal mixed nozzle.

Burner design is crucial in determining the level and amount of emission during the combustion process. Poor atomization results in large ash particles and a higher particulate loading because the fuel droplets may be large enough to make it difficult to burn completely**.** Good atomization is achieved by a smaller burner nozzle hole which contributes to a more complete combustion of the fuel [7]. Air atomizing burners are able to operate at lower levels of excess air and thus provide more efficient combustion with less NOx, SOx, CO and UHC emissions [8]. Combustion occurs due to the rapid oxidation of fuels to produce heat, light, and combustion products (CO2 and water). The combustion of diesel oil is similar to the combustion of other liquid, solid or gaseous fuels and the chemical reactions involved are the same. Complete combustion occurs when the reaction of the fuel and oxidizer is stoichiometric and all of the reactants are consumed. However, this is difficult to achieve and therefore a large amount of excess air is used to ensure complete or near complete combustion. This air is called excess air and is expressed as a percent of the required air. The combustion process can occur in two modes, namely the mode with a flame or a mode without a flame. The characteristics of the flame that can be used as a benchmark for burning a mixture of candlenut biodiesel and pertamina dex [pertadex] are flame temperature, flame height and flame color.

RESEARCH METHODOLOGY

The research method used is the experimental method. This method is used to test the characteristics of the combustion flame in oil burners with candlenut biodiesel fuel, Pertamina dex, and a mixture of Pertamina dex with candlenut biodiesel (Aleurites moluccanus). The composition of the candlenut biodiesel mixture used a mixture of B10 (90% pertadex and 10% biodiesel), B20 (80% pertadex and 20% biodiesel), and B30 (70% pertadex and 30% biodiesel). The characteristics of the flame that were tested were: flame temperature, flame height and flame color. The stages of testing carried out include the following:

1. Set up the burner as shown in Figure 1. below.
2. Perform a slow firing process or preheating, which is heating the burner using a lighter stove from an LPG cylinder for approximately 5 minutes.
3. After the funnel temperature increases and becomes hot, open the compressor valve, and adjust the air flow at 30 l/min.
4. Open the fuel valve [biodiesel/pertadex] at a flow rate of 20 ml/min to 100 ml/min.
5. Light a fire with a mixture of Pertadex fuel with air, using a gas lighter. When the fire is already on, turn off the fire that heats the pipe funnel where the nozzle is, by closing the LPG pipe faucet.
6. After the fire is on, wait a few minutes [3 minutes] to see the stability of the fire.
7. Record the temperature at T1, T2, and T3
8. Taking pictures of the flames
9. Repeat steps 1-8 with a different composition of the fuel and air mixture.

Caption :

1. temperature measuring pole
2. thermocouple
3. combustion chamber
4. fuel nozzle
5. frame
6. stop the fuel valve
7. fuel tank
8. Horder fuel tank
9. protractor
10. air flow valve
11. lpg gas nozzle
12. lpg tube
13. lpg gas hose
14. air hose
15. air flowmeter
16. air compressor

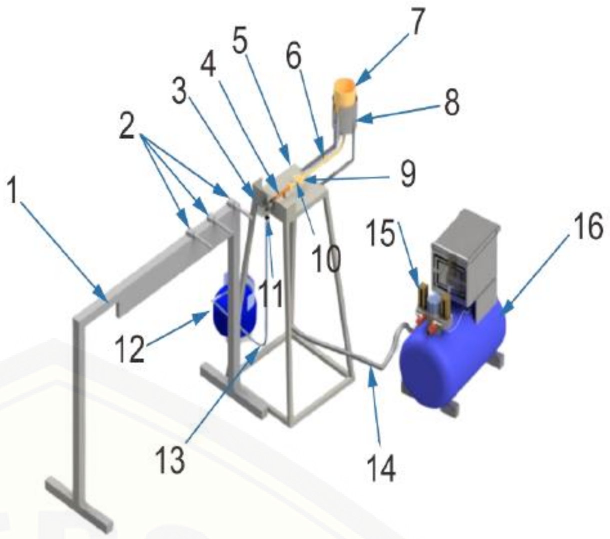


Figure 1. Schematic of the fire characteristics testing tool

RESULTS AND DISCUSSION

Flame Temperature

Data from the results of temperature tests carried out using three thermocouples at predetermined points, namely T1, T2, and T3. The results of the data that have been obtained then produce the average shown in Figure 2 and Figure 3.

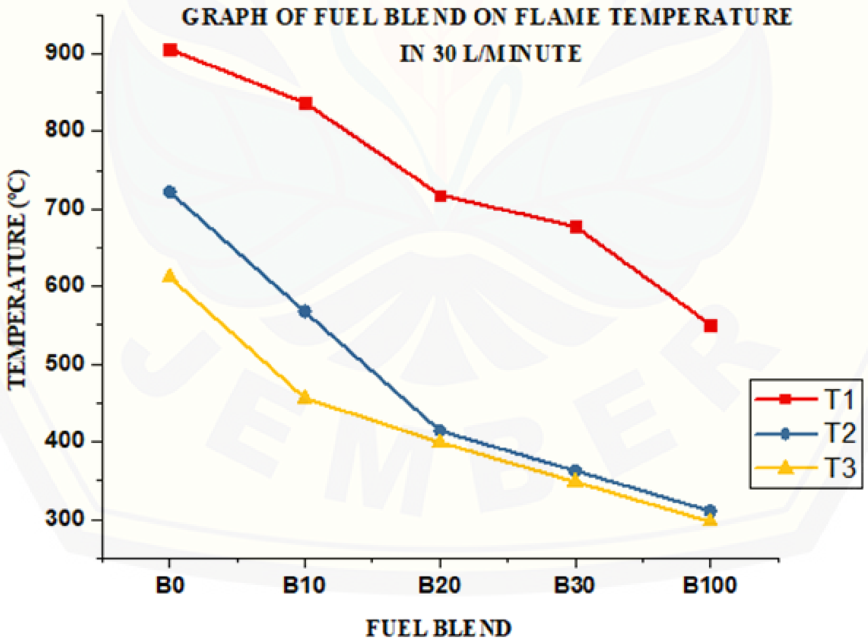


Figure 2. Graph of average temperature results in air 30l/min

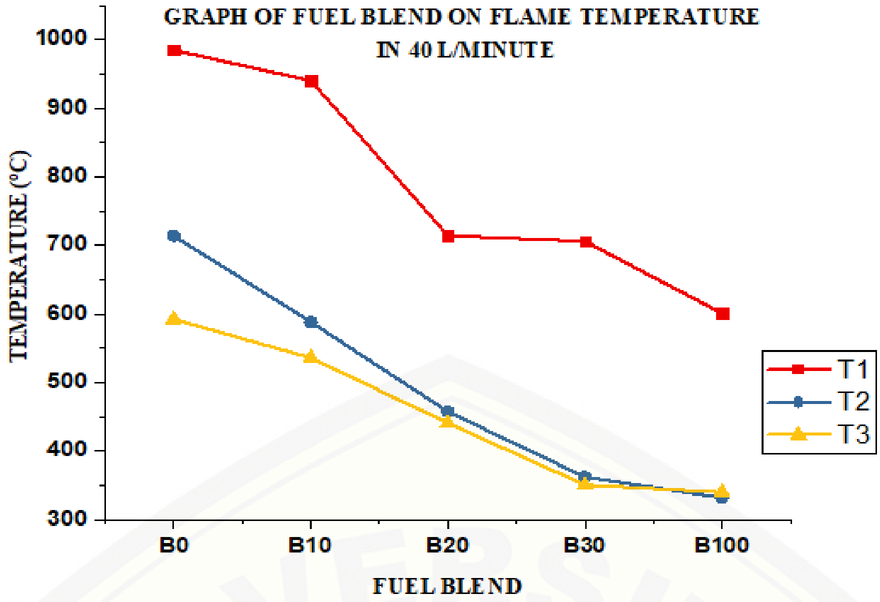
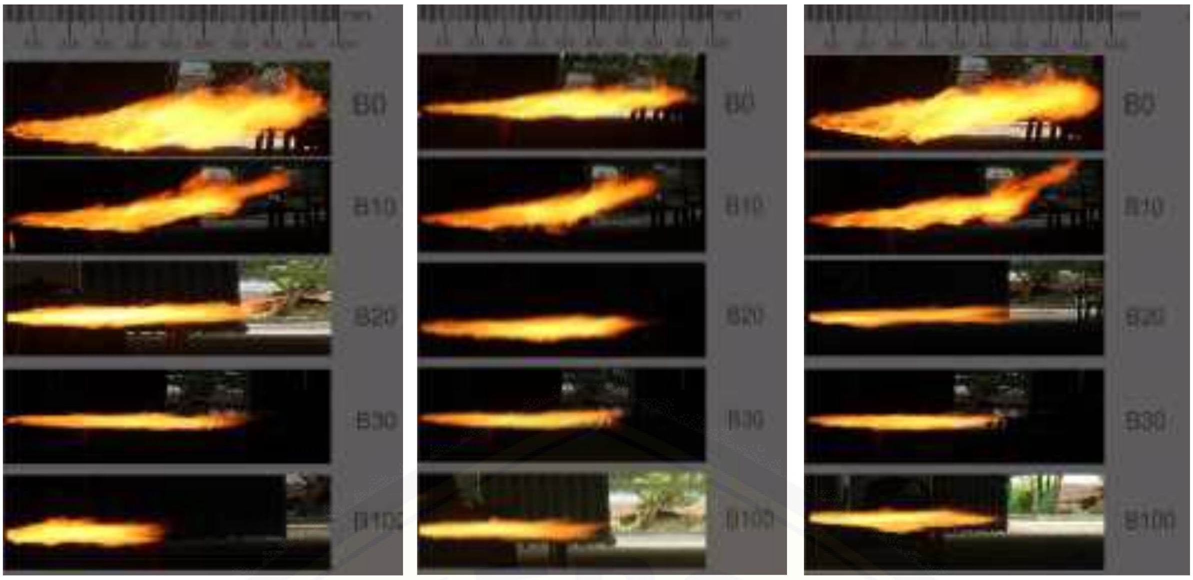


Figure 3. Graph of Temperature and Fuel Mixture in Air 40 l/min

From the graphs shown in Figures 2 and 3, it shows that the more variations of the biodiesel mixture in the fuel, the smaller the temperature that will be produced. Where the thermometer T1 in this study is a few cm above the base so that the flame temperature of T1 is high. At 30 l/minute the highest temperature is at point T1 which is 905.5ºC and the lowest value is at T3 which is 297ºC. The same thing also happened to air at 40 l/minute, where the T1 value reached 984.8ºC, while at T3 it was 332.3ºC. The temperature of the air 30 l/minute and 40/minute there is a difference in the value, which is higher in the air temperature of 40 l/minute. An increase in the amount of oxygen from the combustion air allows for a more stable combustion resulting in higher combustion and better heat transfer temperatures [9]. The temperature at T1 or higher base is due to the complete mixing of fuel vapors and air. Fuel vapor will form flammable fine gases that cause complete combustion, such as in the bottom region (near the nozzle tip) and the core region. Also, this is due to the temperature distribution increasing from the base and decreasing at the midpoint. And at the end of the fire there is a decrease because the fuel mixture is too much so that the combustion is not perfect so that the resulting temperature is low. This is in accordance with Mahfouz's research where the low flame temperature at the tip of the nozzle (base) will then increase first in the core area after which it moves further away from the nozzle, the temperature will decrease [10]. In this study, T1 starts at the core area, then T2 and T3 further away from the nozzle.

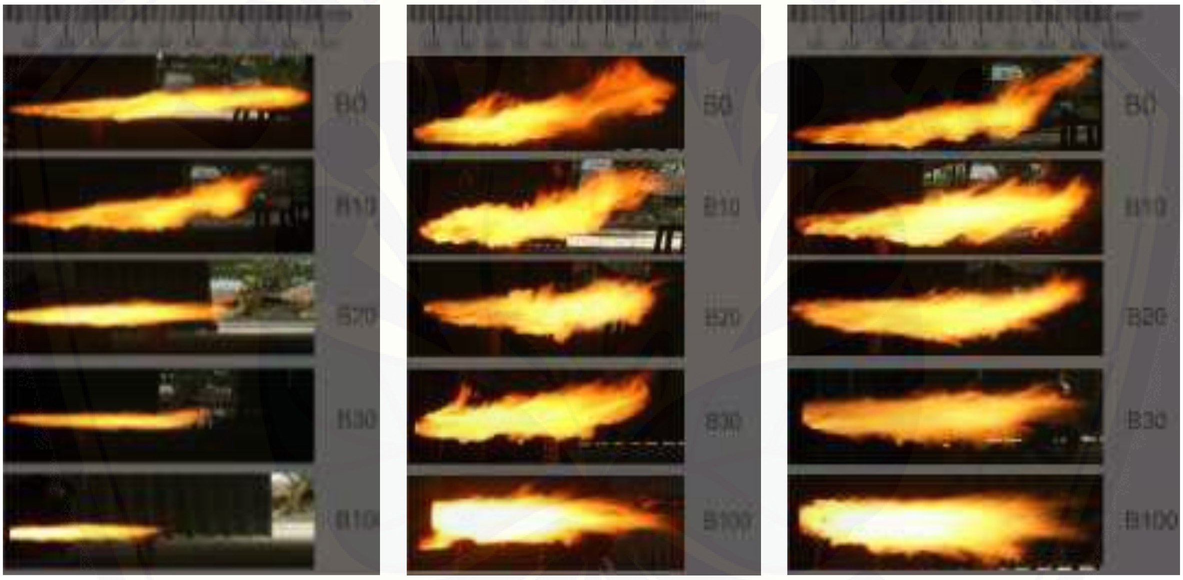
Flame Length

In testing the length of the flame, the results obtained where the variation of the equivalence ratio affects the length of the flame produced as shown in Figures 4 and 5 below:



[a] [b] [c]

Figure 4. Flame length of fire at (a) φ = 0,2 (b) φ = 0,3 (c) φ = 0,4.



[a] [b] [c]

Figure 5. Flame length of fire at: (a) φ = 0.5 (b) φ = 0,7 (c) φ = 0.9

Figure 4 and Figure 5 show that the length of the fire will be directly proportional to the amount of candlenut seed oil biodiesel mixture in pertadex, i.e. the more biodiesel mixture, the longer the flame will decrease. It can be seen from Figures 4 and 5, that the highest flame length value is at variation B0 both at 30 l/min air and 40 l/min air. This can be influenced by the viscosity value of the mixture variation where the lowest viscosity value is at B0 and the highest is at B100. This result is in accordance with the statement namely a lower fuel viscosity results in a smaller fuel droplet size and a smaller droplet size tends to have a higher velocity so that the flame length is longer and vice versa [11]. The higher excess air coefficient at B0 when compared to B10, B20, B30, and B100 could also be a contributing factor to the shorter flame length as shown in Figure 4. and Figure 5. Lower volumetric proportion of fuel components consumed less volatile in the fuel mixture and boiling point variations lead to less fuel nucleation resulting in small bubbles. These bubbles burst to develop secondary droplets at the nozzle, after which the secondary droplets disintegrate into smaller droplets as they move. Reducing the fuel droplet size shortens the time the fuel is in the droplet state, thereby reducing the flame length. In Figure 4 it can be seen that φ = 0.3 and Figure 5 at φ = 0.2 flame length shows almost the same trend for all types of fuel used with a stable incline following the equivalence ratio. At φ = 0.4 and φ = 0.5 the flame becomes longer than the previous condition so the trend looks longer where the flame at B0 shows a large development but is believed to be due to its low viscosity. At φ = 0.7 and φ = 0.9 the length of the flame looks longer, this is indicated by the increasing percentage of flame in each fuel mixture, but it is still dominated by the highest flame length at B0. This is due to the effect of the equivalence ratio in combustion. With an increase in the amount of fuel injection because the equivalence ratio increases but the biodiesel mixture is slightly shorter than the length of the flame and a smaller angle than pertadex fuel because of its viscosity and density [12]. The phenomenon of micro-explosion affects the flame length and flame temperature distribution due to addition of biodiesel and in this case will shorten the flame. The micro-explosion reaction occurs due to differences in the liquid's flash point, viscosity, and density. This is evidenced by the decrease in flame temperature during combustion as well as the length of the flame, as stated [13].

Flame Color

The data from the test results for the percentage of the blue flame color are as shown in Figure 6 and Figure 7. below.

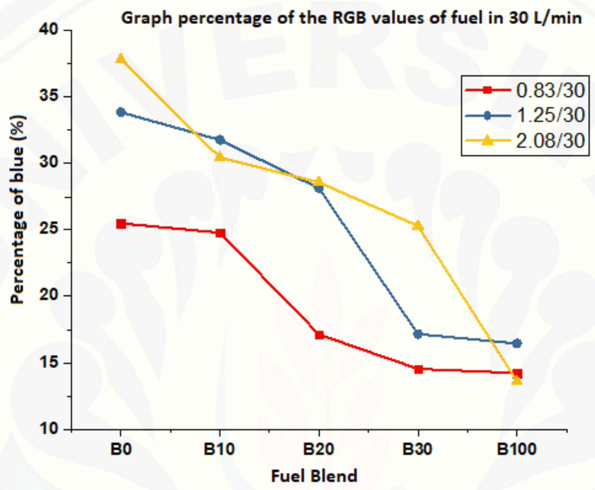


Figure 6. Percentage of Blue Flame Color and Fuel Mix in Air 30 L/min

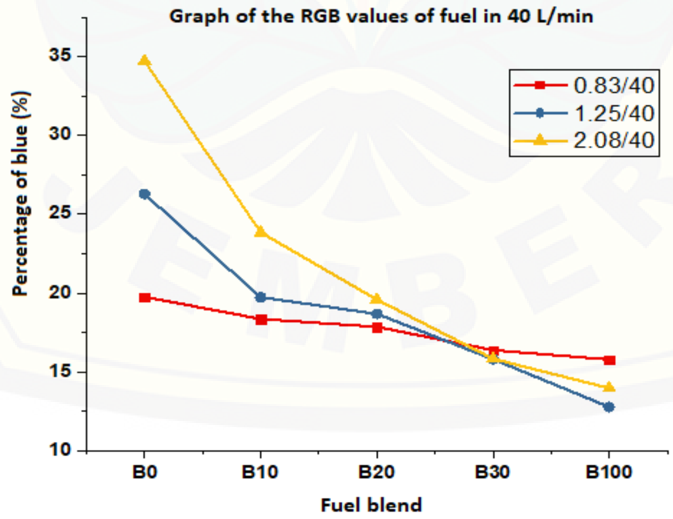


Figure 7. Percentage of Blue Flame Color and Fuel Mixture in Air 40 L/min

The percentage of the color of flame is blue and the fuel mixture in air 40 l/min. In testing the percentage value of RGB blue fuel mixture B0 with air variation of 30 l/minute, the value is 37.7%. This value when compared to the blue RGB value of the B0 fuel mixture at 40 l/min air is much higher. This is because the fuel is completely mixed with air using the diffusion combustion method, where the fuel and air mix by itself in a spray burner

burner. These results are in accordance with research conducted which said that the more addition of biodiesel, the smaller the fire will be (short) [14]. This is influenced by the large density of biodiesel which causes the fuel to be difficult to oxidize. The blue color produced in the combustion process indicates that the fuel has been completely mixed with the air. The percentage of blue value in air at 40 l/min is greater than the percentage in air at 30 l/min. This is because fires that lack oxygen (poor oxygen) will tend to be red and result in a decrease in the calorific value, while fires that are rich in oxygen will tend to be blue in color and will increase the calorific value [15].

CONCLUSION

1. The addition of variations in the biodiesel mixture will affect the temperature value, flame length and color of the combustion flame.
2. The more biodiesel increases, the combustion temperature produced, the length of the flame and the percentage of the blue color will decrease.
3. The highest temperature and the highest percentage of blue values are at B0 and the lowest is at B100, both at 30 l/min and 40 l/min. The highest percentage of blue value is in the variation of B0 and the lowest value is in B100, both at 30 l/min and 40 l/min.
4. Air consumption also affects the value of the combustion temperature. Variations in air at 40 l/min resulted in a higher temperature compared to air at 30 l/min.

REFERENCES

[1] S. Lee, S. Kum, C. Lee, “An experimental study of a cylindrical multi-hole premixed burner for the development of a condensing gas boiler,” Energy, Vol. 36, Pp. 4150 – 4157, 2011.

[2] C.E. Baukal, R. Hayes, M. Grant, P. Singh, D. Foote, “Nitrogen Oxides Emissions Reduction Technologies in the Petrochemical and Refining Industries,” Environmental Progress, Vol. 23, No. 1, pp. 19 – 28, 2004.

[3] T.V. Mathew, 2014. “Fuel Consumption and Emission Studies,” Transportation Systems Engineering, Pp. 1 – 25.

[4] B. Repic, A. Eric, D. Djurovic, A. Marinkovic, G. Zivkovic, “Experimental determination of the swirl burner laboratory models of hydraulic resistance," Procedia Engineering, vol. 42, Pp. 672-682, 2012.

[5] S. Jugjai, C. Pongsai, “Liquid Fuels-Fired Porous Burner,” Combustion Science and Technology, Vol. 179, No. 9, Pp. 1823 – 1840, 2007.

[6] E.O. Olson, “Fuel Nozzles for Oil Burners, Technical Aspects of Applications,” Pp. 1 – 11, 1999.

[7] F.J. McGarry, C.J. Gregory, “A Comparison of the size Distribution of Particulates Emitted from Air, Mechanical and Steam Atomized Oil-Fired Burners,” Journal of the Air Pollution Control, Vol. 22, No. 8, Pp. 636-639, 2012.

[8] R.E. Hall, W.M. Cooke, R.L. Barbour, “Comparison of air Pollutant Emissions from Vaporizing and Air atomizing Waste Oil Heaters”, Journal of the Air Pollutant Control Association, Vol. 33, No. 7, Pp. 683-687, 2012.

[9] B.O. Owiti, “Performance of Waste Lubrication Oil Burner for Process Heating in Small to Medium Enterprises”, Master of Science (Mechanical Engineering). Jomo Kenyatta University. JKUAT, 2015.

[10] Mahfouz, A. Emara, and A.L. Fatih, “Effect of Waste Cooking - Diesel Oils Blends on Performance, Emissions and Combustion Characteristics of Industrial Oil Burner”, International Journal for Research in Applied Science & Engineering Technology, Vol. 9, No. 5, Pp. 2321-9653, 2017.

[11] Luka, R. Ejilah, and S. Owhor, “Effect of Diesel Fuel Blend on Flame and Emission Characteristics of Used Engine Oil as Heating Fuel Using Swirl Waste Oil Burner”, Environmental and Climate Technologies, 24 (1), Pp. 545-561, 2020.

[12] Khalid, M. Suardi, M. Chin., and Amirnordin, “Effect of Biodiesel-water-air derived from Biodiesel Crude Palm Oil Using Premix Injector and Mixture Formation in Burner Combustion”, Energy Procedia, 111, Pp. 877-884, 2016.

[13] Mahfouz, A. Emara, M.S. Gad, A. El-fatih, A.F. El-Sherif, and H.S. Ayoub, “Thermal Flame Spectroscopy of Various Diesel Fuels and Their Blends with Waste Cooking Oil Through Using Coaxial Burners”, Egyptian Journal of Petroleum, Vol. 28, No. 3, Pp. 307-313, 2019.

[14] J.Z. Rosafira, “Characteristics of Diffusion Flame of Biodiesel Oil from Pecan Seed Oil (*Aleurites Moluccan*a)”, Final paper. Jember: Faculty of Engineering Jember, 2019.

[15] D. Listyadi, “Analysis of Characteristic of Combustion Flame Biogas Mixed with Butane”, International Journal of Advanced Research, Vol. 7, No. 1, Pp. 12284 – 12287, 2018.